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TECHNICAL REPORT

A HYDRAULICALLY OPERATED LABORATORY FURNACE WITH RESISTANCE THERMOMETER TEMPERATURE CONTROL

By

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ABSTRACT

A high temperature, rapid loading furnace for study of small specimens is described. Globar heating elements allow operation up to 1500°C. The furnace can be operated using reducing, neutral or oxidizing atmospheres. Temperature is controlled electronically with a resistance-thermometer actuated Thermocap relay to $\pm$ 1°C. A hydraulic lift permits easy and rapid positioning of the hot zone relative to the specimen.

INTRODUCTION

In the study of metal-ceramic mixtures a series of specimens had to be fired in oxidizing, reducing, or neutral atmospheres. The specimens had to be introduced into the furnace atmosphere at elevated temperatures (600 to 1500°C.) and removed while at those same temperatures. Firing time extended from a few minutes to several hours.

The primary problem was construction of a controlled atmosphere furnace that could also be used as a general laboratory furnace. A study of the large variety of laboratory furnaces failed to reveal one which would fit the whole needs of this laboratory. Consequently, a furnace was constructed and modified several times before this present model was perfected.

To meet these requirements, a furnace was constructed which:

1. Has a gas "impervious" muffle in which the atmosphere can be changed easily and quickly.
2. Has a relatively large heat capacity so that introduction of a sample at an elevated temperature will not materially affect the temperature of the furnace.
3. Has an automatic temperature control that will maintain the furnace temperature to within $\pm$ 1°C.
4. Is easily and rapidly manipulated by one man.

A globar furnace with a gas impervious muffle, a hydraulic lifting device and an automatic temperature controller, constitute the basic components of the apparatus.

CONSTRUCTION DETAILS

A. Furnace

The muffle (Figure 1) consists of a vertical 36 inch combustion tube 1½ inches in inside diameter. The tube is necked down at the upper end to fit the gas supply tubing. This tube is a commercially obtainable item. (McDanel - Zircotube)

This muffle is surrounded by eight Globar heating elements placed in a circle inside an eight-inch fireclay muffle. The fireclay muffle is surrounded by light MgO and the whole contained in a metal drum 21½ inches high and 18 inches in diameter.

Specimens are supported on a 2 foot alundum tube of 1 inch outside diameter. The alundum support is cemented into a pedestal fitted with an exit tube for gases. The pedestal base keeps a spring tension upward on the tube support and can be levelled to keep the alundum tube precisely lined up with the muffle. Light gases are forced down and withdrawn through the pedestal outlet; the heavy gases are withdrawn from the top of the muffle.

The lower ends of the globars rest upon a transite plate and are held in a vertical position. This arrangement minimizes the strain on the heating elements since their own weight keeps them in compression.

The larger heat capacity of Globars over that of a resistance winding heating element is desirable to permit a minimum temperature loss and a quick recovery when cold samples are introduced suddenly.

B. Lifting Mechanism

The furnace is moved vertically within a rigid frame. The specimen support is stationary and the furnace may be moved up or down over it by the lifting mechanism. The furnace is held between two upright angle iron braces which act as supports and guides. A pulley is located at the top of each side of this frame and cables run from the top of the furnace over these pulleys and onto a drum. Cables supporting the counterbalance weights are also on this drum.

The drum is driven by a rack and pinion which is motivated by a hydraulic ram. The ram obtains its sole power from the city water lines.

The operator merely has to turn on the water through a four way

valve to obtain power. A twist to one side raises the furnace, and to the other side lowers it. Hydraulic power lends to smoother operation than that obtained by other mechanisms.

One person can turn the valve, load or unload a specimen and then reverse the valve in a very few seconds.

All power leads are flexible to allow for furnace travel.

C. Temperature Control

An impervious muffle was used in lieu of an entirely gas-tight furnace to prevent undue flushing times involved with porous refractory materials and to keep gases such as hydrogen, away from the globar heating elements. A thermocouple could not be used because of hydrogen embrittlement. It was found quite advantageous as a time saver and as a safety factor to flush only a small volume with hydrogen instead of the whole furnace. By using a muffle the platinum resistance thermometer for control could be used outside the atmosphere and closer to the heating elements. Any change in temperature is then sensed sooner and corrective action taken by the control mechanism.

Temperature control is effected by the use of a few turns of non-inductively wound 80% platinum - 20% rhodium wire around the muffle tube. This wire serves as a resistance thermometer as it acts as one arm of a Wheatstone bridge. Figure 2. The bridge current is supplied by a wet cell at a potential of two volts. Any unbalance of the bridge is detected by a sensitive galvanometer. A light metal flag moving between two fixed condenser plates is attached to the needle of the galvanometer. Consequently, there is no mechanical control. Motion of the galvanometer needle, as the bridge goes out of balance, reflects a change in capacitance of the condenser, which is sensed by an electronic relay (Thermocap) which closes a relay, shorting out a portion of the regulating reactor thus

allowing more current to pass through the power transformer. Temperature control is effected, therefore, by regulating the amount of current flowing through the primary side of the power transformer; temperature below set point both relays closed, temperature at set point one relay closed, temperature above set point both relays open.

When the furnace is at a desired temperature, the bridge is adjusted to zero current flow by changing the value of a high-sensitivity variable resistance (helipot) in one leg of the bridge. The null point of the bridge is measured by the sensitive galvanometer. The direction of the galvanometer deflection is dependent on the temperature fluctuation. Periodic calibration of the unit is necessary to avoid small temperature drifts because of recrystallization and oxidation of the sensing element.

TYPICAL OPERATION

In this laboratory a typical operation would start by bringing the furnace up to the desired temperature. The gas to be used as an atmosphere is then admitted and the flow adjusted. When at temperature, the automatic control is put into operation by balancing the bridge at the particular temperature to which the furnace has been brought, then the standard thermocouple is removed.

When the gas has had time to permeate the whole muffle, the sample is brought to the furnace. The water valve is turned to raise the furnace, the sample placed on the tube support and the valve turned again to lower the furnace. After the furnace is returned to its operating position the operator checks to see that the muffle tube properly seats itself on the rubber seal between it and the support tube. This completes all the manipulation necessary for loading and firing.

The unloading requires partly raising the furnace and keeping the sample in the lower part of the muffle until it cools. When the sample is cool the furnace is raised completely and the sample removed. This process assures that the sample remains in the desired atmosphere until it

reaches room temperature. If quenching is desired the furnace is moved away from the sample rapidly and the sample plunged into the quench bath.

SUMMARY

A furnace has been developed that greatly facilitates loading and unloading operations while allowing for atmospheric control. After the initial adjustments of gas flow and temperature the furnace is as near to automatic as is possible. A flick of a valve opens or closes the firing chamber to use. Manual control of temperature and the working parts is almost eliminated after initial adjustments are made. Changing from one atmosphere to another is simple.

The furnace has been used for a variety of purposes in this laboratory. Oxide layer penetration, sintering in a controlled atmosphere, and thermal diffusivity experiments have been run in the furnace to date. Any experiments involving introduction into a heated atmosphere and quick removal or just plain firing up to a temperature with accompanying cooling with the furnace or quenching may be accomplished with this versatile apparatus.

Construction of this furnace was made possible as part of the Office of Naval Research Contract N6-ori-143.

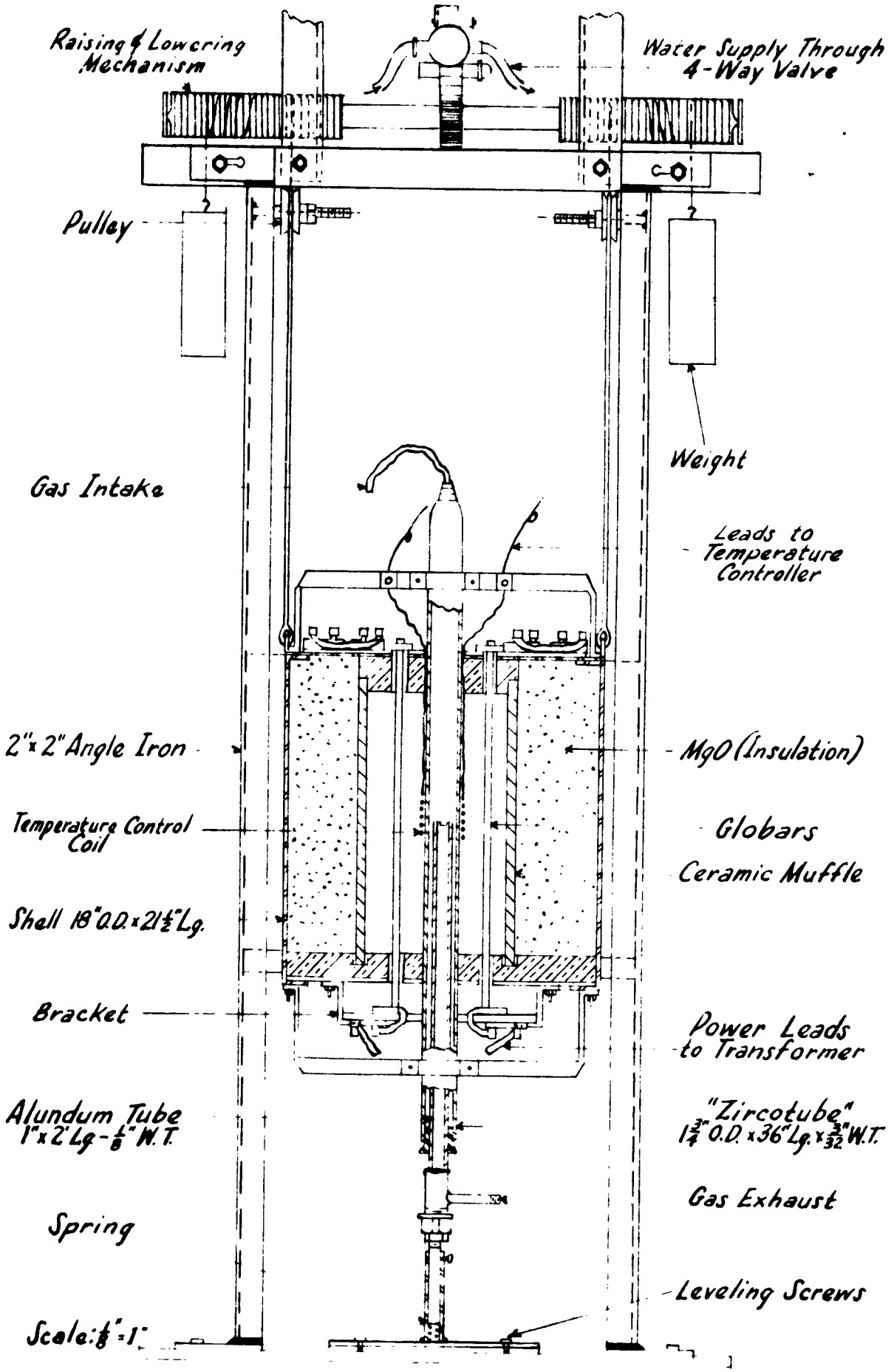

Fig. 1. FURNACE DETAILS

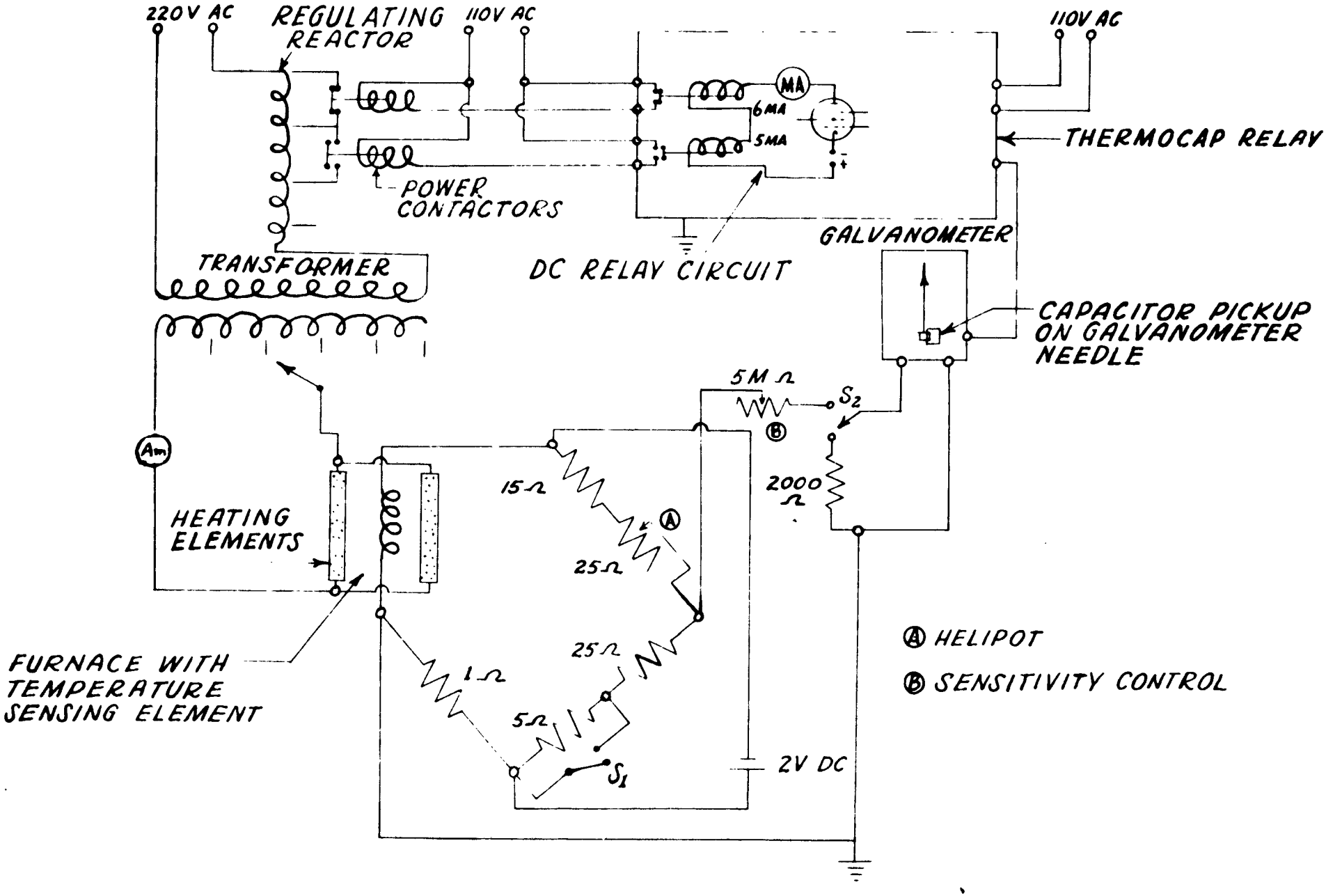

FIG. 2. SCHEMATIC DRAWING OF TEMPERATURE CONTROL CIRCUIT

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